(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 015 317 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
14.01.2009 Bulletin 2009/03

(51) Int Cl.:
H01B 11/18 *(2006.01)* ***H01B 13/016*** *(2006.01)*

(21) Application number: **07290882.5**

(22) Date of filing: **11.07.2007**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC MT NL PL PT RO SE SI SK TR
Designated Extension States:
AL BA HR MK RS

(71) Applicant: **Alcatel Lucent**
75008 Paris (FR)

(72) Inventors:
- **Greiner, Martin**
  30966 Hemmingen (DE)
- **Mientkewitz, Olaf**
  30952 Ronnenberg (DE)

(74) Representative: **Richardt, Markus Albert**
Richardt Patents & Trademarks
Leergasse 11
65343 Eltville am Rhein (DE)

Remarks:
Amended claims in accordance with Rule 137(2) EPC.

(54) A coaxial cable

(57) A coaxial cable comprising a dielectric layer between the inner and outer conductor of the coaxial cable **characterized in that** the dielectric layer consists of a cross-linked and foamed plastic is disclosed.

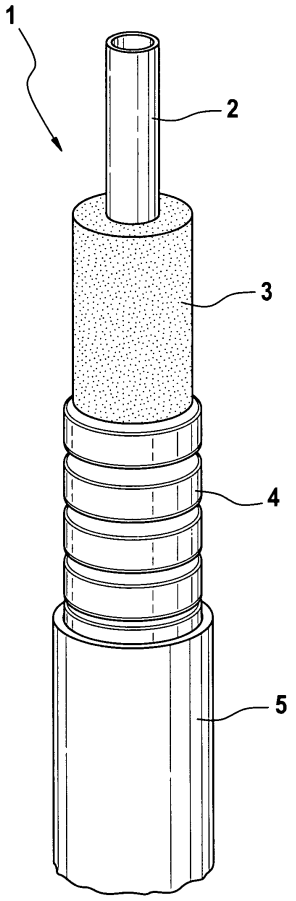

Fig. 1

EP 2 015 317 A1

Description

Field of the invention

[0001] The invention relates to a coaxial cable and a method of producing a coaxial cable.

Background

[0002] A coaxial cable is an electrical cable consisting in essence of an inner conductor that is surrounded by one or more layers of insulating material that are surrounded by a cylindrical conducting sheath which is commonly referred to as outer conductor. The outer conductor is usually surrounded by a final insulating layer which is also denoted as jacket.

[0003] Coaxial cables are used as high-frequency transmission lines to carry a high-frequency or broadband signal. Because the electromagnetic field carrying the signal exists ideally only in the space between the inner and outer conductors, it cannot interfere with or suffer interference from external electromagnetic fields.

[0004] Due to ohmic losses, a part of the electric power of the signal that is carried by a coaxial cable is transformed into heat. The heat causes an increase of temperature of the coaxial cable with a relative strong temperature gradient over a cross-section of the coaxial cable with decreasing temperatures from the inner conductor to the outer conductor. In case the melting temperature of the dielectric layer or dielectric layers in between the inner and outer conductor is exceeded, the cable is destroyed as the inner conductor is not anymore mechanically attached to the inner surface of the dielectric layer. The melting temperature of the dielectric layer between the inner and outer conductor poses therefore a limit to the maximal electrical power that can be transported over the coaxial cable.

[0005] Polyolefins are preferably used as material for the dielectric layer as they provide relative low dielectric loss and are relatively easy to handle and process. A polyolefin is a polymer produced from a simple olefin, or alkene as a monomer. An equivalent term is polyalkene. Polyethylene and polypropylene are examples of a polyolefin. Polyethylene is the polyolefin produced by polymerizing the olefin ethylene and polypropylene is made from propylene.

[0006] Polyolefins have however the disadvantage that their melting temperatures are relative low so, when used as material for the dielectric layer in a coaxial cable, the relative amount of electric power that can be transported by the coaxial cable will be relatively low.

[0007] Cross-linking relates to the process of introducing cross-links between the polymers of for example the dielectric layer consisting of a polyolefin such as polyethylene. Cross-links are covalent bounds linking one polymer chain to another. They are the characteristic property of thermosetting plastic materials. Cross-links are formed by chemical reactions that are initiated by heat and/or pressure, or by the mixing of an unpolymerized or partially polymerized resin with various chemicals. Cross-linking can be induced in materials that are normally thermoplastic through exposure to radiation. A cross-linked polyolefin has the advantage that it melts at a higher melting point.

[0008] JP 53096486 A describes a manufacturing method for coaxial power cables. In order to prevent blowing, deformation, etc due to thermal pressurization of the dielectric layer of a coaxial cable, cross-linked dielectric layers are formed except of the innermost dielectric layer in such a manner that polyethylene polymerized with silicone system compound and the existence of silanol system catalyst is exposed in the water.

[0009] JP 04345622 A describes a process for cross-linking the cover of a cable by irradiating it with electron beams, wherein a desired part of the cross-linked cover is located at the greatest penetration distance part which absorbs electron beams. A film made of a material which is the same as the material constituting the cover is interposed or electron beams of different energies are used to allow the cover to uniformly absorb electron beams. Because the entire cover can absorb uniformly electron beams and excessive electrons cannot remain, uniform cross-linked can be performed.

[0010] JP 02061600 A describes an electron beam irradiation cross-linking device.

[0011] JP 2005235629 A describes a polyethylene insulation composition for cross-linking by electron beam irradiation and a high-frequency coaxial cable using this. The polyethylene insulation composition for cross-linking by electron beam irradiation contains 0.03 to 0.20 weight percent of a hindered phenol-based anti-oxidizing agent in polyethylene whose density is 0.920 to 0.951 grams per milliliters and melt tension is 4 to 20 grams.

[0012] It is an object of the invention to disclose an alternative coaxial cable that is able to transport the relative high electrical power. It is another object to describe a method of producing such a coaxial cable.

Summary of the invention

[0013] According to a first aspect of the invention, a coaxial cable is disclosed. In accordance with an embodiment of the invention, the coaxial cable comprises a dielectric layer between the inner and outer conductor of the coaxial cable. The coaxial cable is characterized in that the dielectric layer consists of a cross-linked and foamed plastic. Due to the cross-linking, the dielectric layer keeps its elastic properties even at higher temperatures and thus remains fixed to the inner conductor. Due to the cross-linking, the dielectric loss factor of the dielectric material is increased. However, as the dielectric material consists of foamed plastic material, the increase of the dielectric loss is not dramatic.

[0014] In accordance with an embodiment of the invention, the plastic material is a mixture of high-density polyethylene (HDPE) and low-density polyethylene

(LDPE). These materials are relatively cheap and provide a relative low dielectric loss factor. Furthermore, they are easy to handle and readily available commercially.

[0015] In accordance with an embodiment of the invention, the dielectric plastic consists of at least 50% high-density polyethylene. The foamed and cross-linked dielectric plastic is thus made to at least 50% of high-density polyethylene.

[0016] In accordance with an embodiment of the invention, the cross-linked foamed plastic has a density in the range between 120 and 500 kilograms per cubic meters. According to a second aspect of the invention, there is provided a method of producing a coaxial cable. In accordance with an embodiment of the invention, the method comprises the step of arranging a layer of foamed plastic around an inner conductor of the coaxial cable in a way that the outer surface of the inner conductor is in contact with the layer of foamed plastic. The dielectric layer of foamed plastic is cross-linked, wherein the foamed plastic is transformed into cross-linked foamed plastic. In a further step, an outer conductor of the coaxial cable is arranged around the outer surface of the layer of cross-linked foamed plastic. Then, a non-conductive jacket is arranged around the outer conductor of the coaxial cable.

[0017] A person skilled in the art will notice that the method might further comprise intermediate steps. For example, the layer of foamed plastic might not be a single layer. Instead, a plurality of layers formed, e.g., from different foamed plastics might be arranged between the inner and outer conductor. The plurality of layers might then be arranged one by one around the inner conductor.

[0018] In accordance with an embodiment of the invention, the layer of foamed plastic is cross-linked by electron beam irradiation.

[0019] In accordance with an embodiment of the invention, the electron beam irradiation relates to an absorbed dose of 75-200 kGy.

[0020] In accordance with an embodiment of the invention, the foamed dielectric layer is chemically cross-linked.

[0021] The skilled person will appreciate that the steps of cross-linking the foamed plastics and arranging a layer of foamed plastic around the inner conductor of the coaxial cable are inter-related and cannot be separated into two steps. The reason is that chemical cross-links are formed by chemical reactions that are initiated by heat and/or pressure or by the mixing of an unpolymerized or partially polymerized resin with various chemicals and therefore chemical cross-linking has to be done while arranging the layer of foamed plastic around the inner conductor.

[0022] According to a third aspect of the invention, there is provided an apparatus for producing a coaxial cable. In accordance with an embodiment of the invention, the apparatus comprises means for arranging a layer of foamed plastic around an inner conductor of the coaxial cable such that the outer surface of the inner conductor is in contact with the layer of foamed plastic. The apparatus has means for cross-linking the foamed plastic, wherein the foamed plastic is transformed into cross-linked foamed plastic. Additionally, the apparatus comprises means for arranging an outer conductor of the coaxial cable around the outer surface of the layer of cross-linked foamed plastic and means for arranging an non-conductive jacket around the outer conductor of the coaxial cable.

Brief description of the drawings

[0023] In the following various embodiments of the invention will be described in greater detail by way of example only making reference to the drawings in which:

Figure 1 shows a perspective cut-away view showing a coaxial cable in accordance with the present invention,

Figure 2 shows a flow diagram illustrating steps performed by a method in accordance with the invention.

Detailed description

[0024] Fig. 1 shows a perspective cut-away view showing a coaxial cable 1 in accordance with the present invention. The coaxial cable 1 comprises an inner conductor 2. The inner conductor 2 consists for example of copper and has the form of a wire or of a tube. The coaxial cable 1 furthermore comprises a dielectric layer 3 that is arranged around the inner conductor 2 such that the inner surface of the dielectric layer 3 is in mechanical contact with the outer surface of the inner conductor 2. The coaxial cable 1 furthermore comprises an outer conductor 4 which is typically made out of copper or of another metal and which is arranged around the dielectric layer 3 such that the inner surface of the outer conductor 4 is in mechanical contact with the outer surface of the dielectric layer 3. The coaxial cable 1 furthermore comprises a jacket 5 that is arranged at the outside of the outer conductor 4 and that typically consists of a plastic material.

[0025] The dielectric layer 3 of the coaxial cable is characterized in that it consists of a cross-linked and foamed dielectric plastic. Due to the cross-linked structure of the dielectric plastic, the melting temperature of the dielectric layer is increased with respect to the unlinked layer consisting of the same material, for example of polyethylene. The coaxial cable therefore allows for the transport of electromagnetic signals with a relative high power.

[0026] As the dielectric layer is furthermore a foamed structure which counteracts against the increase of the dielectric loss of the dielectric material of which the dielectric layer consists as the dielectric loss is increased due to the cross-linking. Thus, the coaxial cable in accordance with the invention allows for the transmission of electromagnetic signal having a relative high power

and provides nevertheless a satisfying dielectric loss.

[0027] The dielectric layer 3 consists preferably of a dielectric plastic which is a mixture of high-density polyethylene and low-density polyethylene, wherein preferably the dielectric plastic consists of at least 50% high-density polyethylene.

[0028] Fig. 2 shows a flow diagram illustrating steps performed by a method in accordance with the invention for producing a coaxial cable. According to step 200, a layer of foamed plastic is arranged around an inner conductor of the coaxial cable such that the outer surface of the inner conductor is in contact with the layer of foamed plastic. According to step 202 of the method in accordance with the invention, the layer of foamed plastic is cross-linked, wherein the foamed plastic is transformed into cross-linked foamed plastic. According to step 204 of the method in accordance with the invention, an outer conductor of the coaxial cable is arranged around the outer surface of the layer of cross-linked foamed plastic. According to step 206 of the method in accordance with the invention, a non-conductive jacket is arranged around the outer conductor of the coaxial cable.

List of Reference Numerals

[0029]

1	Coaxial cable
2	Inner conductor
3	Dielectric layer
4	Outer conductor
5	Jacket

Claims

1. A coaxial cable (1) comprising a dielectric layer (3) between the inner conductor (2) and outer conductor (4) of the coaxial cable **characterized in that** the dielectric layer consists of a cross-linked and foamed plastic.

2. The coaxial cable of claim 1, wherein the cross-linked and foamed plastic is a mixture of high-density polyethylene and low-density polyethylene.

3. The coaxial cable of claim 2, wherein the cross-linked and foamed plastic consists of at least 50% high-density polyethylene.

4. The coaxial cable of claim 1, wherein the cross-linked and foamed plastic has a density in the range between 120 and 500 kilograms per cubic meters.

5. A method of producing a coaxial cable (1) comprising:

   - arranging a dielectric layer (3) of foamed plastic around an inner conductor (2) of the coaxial cable such that the outer surface of the inner conductor is in contact with the dielectric layer of foamed plastic;
   - cross-linking the dielectric layer of foamed plastic, wherein the foamed plastic is transformed into cross-linked foamed plastic;
   - arranging an outer conductor (4) of the coaxial cable around the outer surface of the dielectric layer of cross-linked foamed plastic;
   - arranging a non-conductive jacket (5) around the outer conductor of the coaxial cable.

6. The method of claim 5, wherein the dielectric layer of foamed plastic is cross-linked by electron beam irradiation.

7. The method of claim 6, wherein the electron beam irradiation relates to an absorbed dose of 75-200 kGy.

8. The method of claim 5, wherein the dielectric layer (3) of foamed plastic is chemically cross-linked.

9. An apparatus for producing a coaxial cable (1) comprising:

   - means for arranging a dielectric layer (3) of foamed plastic around an inner conductor (2) of the coaxial cable such that the outer surface of the inner conductor is in contact with the layer of foamed plastic;
   - means for cross-linking the dielectric layer of foamed plastic, wherein the foamed plastic is transformed into cross-linked foam plastic;
   - means for arranging an outer conductor (4) of the coaxial cable around the outer surface of the layer of cross-linked foamed plastic;
   - means for arranging a non-conductive jacket (5) around the outer conductor of the coaxial cable.

Amended claims in accordance with Rule 137(2) EPC.

1. A coaxial cable (1) comprising a dielectric layer (3) between the inner conductor (2) and outer conductor (4) of the coaxial cable, wherein the dielectric layer consists of a cross-linked and foamed plastic, wherein the coaxial cable is **characterized in that** the cross-linked and foamed plastic has a density in the range between 120 and 500 kilograms per cubic meters.

2. The coaxial cable of claim 1, wherein the cross-linked and foamed plastic is a mixture of high-density polyethylene and low-density polyethylene.

3. The coaxial cable of claim 2, wherein the cross-linked and foamed plastic consists of at least 50% high-density polyethylene.

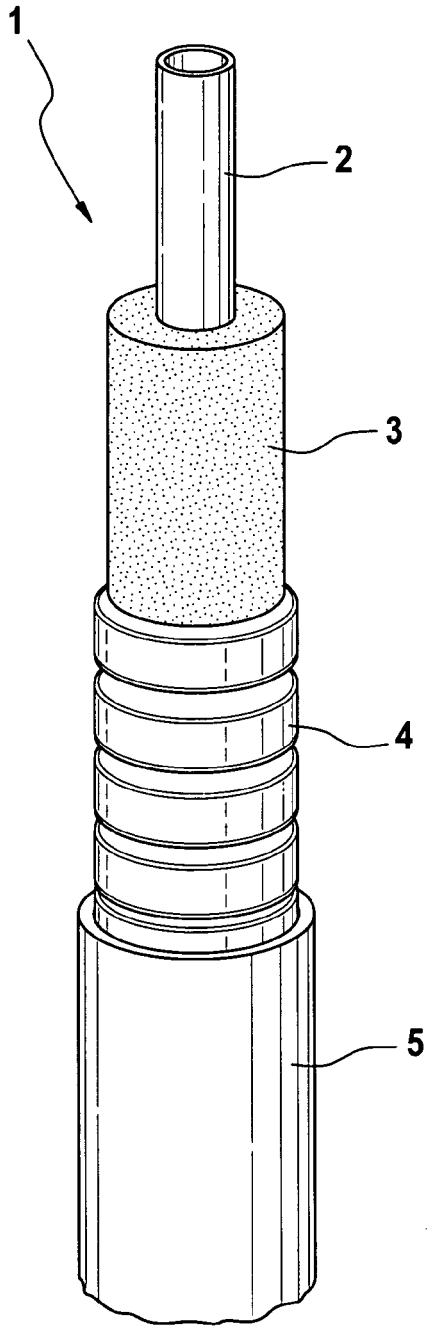

Fig. 1

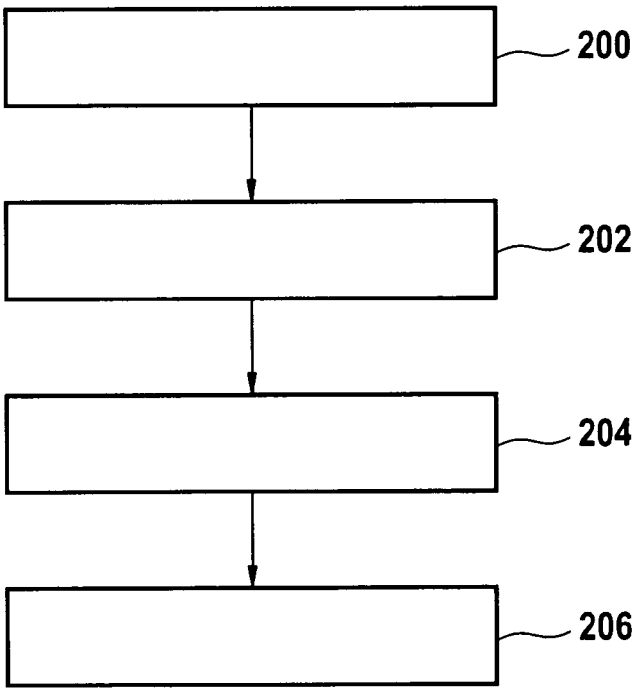

Fig. 2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 29 0882

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JP 07 272552 A (SHOWA ELECTRIC WIRE & CABLE CO) 20 October 1995 (1995-10-20) * abstract; figure 1 * * paragraphs [0008], [0016] *	1-9	INV. H01B11/18 H01B13/016
X	DATABASE WPI Week 200680 Derwent Publications Ltd., London, GB; AN 2006-782301 XP002457865 & CN 1 760 996 A (YUETING ELECTRONIC CABLES CO LTD) 19 April 2006 (2006-04-19) * abstract *	1	
A	JP 08 306250 A (SUMITOMO ELECTRIC INDUSTRIES) 22 November 1996 (1996-11-22) * abstract; figure 1 *	2,3	
A	US 2002/088641 A1 (MURGA PATRICIO G [MX] ET AL) 11 July 2002 (2002-07-11) * paragraph [0025] - paragraph [0026] *	1	

TECHNICAL FIELDS SEARCHED (IPC)

H01B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	7 November 2007	Colombo, Alessandro

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

1

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 07 29 0882

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

07-11-2007

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 7272552 A	20-10-1995	JP 3654536 B2	02-06-2005
CN 1760996 A	19-04-2006	NONE	
JP 8306250 A	22-11-1996	JP 3239684 B2	17-12-2001
US 2002088641 A1	11-07-2002	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 53096486 A **[0008]**
- JP 04345622 A **[0009]**
- JP 02061600 A **[0010]**
- JP 2005235629 A **[0011]**